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THE FAUNA OF THE DEVONIAN FORMATION AT MILWAUKEE, WISCONSIN

THE best, and until recently, the only known area of Devonian rocks in Wisconsin lies immediately north of Milwaukee and furnishes the Milwaukee hydraulic cement of commerce. This rock, in the localities where it is exposed, is a limestone, rich in magnesia, alumina, iron and silica. The best known exposure is in the valley of the Milwaukee River, about half a mile north of the present city limits. At this point many acres of the rock are accessible, forming the bed of the river, and stretching away on either side under alluvial and drift deposits, the latter of which constantly increase in thickness with the distance from the river. The formation is here about twenty five feet in thickness. Its surface may be thirty feet above the level of the lake, which lies a mile and a half to the east. There is a slight dip towards the southeast. The formation rests upon a dark, porous limestone supposed to be of Lower Helderberg age, without fossils. Three miles further north, at the edge of Lake Michigan, is an outcrop which rises slightly above the water level, and is about twenty feet thick. A shaft sunk at this place discloses layers corresponding to those of the lower twenty feet of the quarry on the river. Five miles north of the latter and about three miles further west there is a third exposure in a railway cut, at a considerable height above the river which flows near by; but the deep drift in the neighborhood of the cut has prevented any determination of the extent of the formation in this locality.

Within the past five years it has been found necessary to make additional provision for the city's water supply. In carrying out this provision a shaft was sunk to a depth of one hundred and thirty feet at the edge of the beach at the head of North Avenue, and from the bottom of this shaft a tunnel was bored extending out thirty-two hundred feet under the lake. As a preliminary to this undertaking test bores were made at a num-

ber of points. One of these, at a point very near the place where the shaft was finally sunk, revealed the following section, as shown by the records of the City Engineer's office. At the depth of forty two feet below water level, black shale was found, underlying strata of sand, gravel, and red and blue clay; at fifty seven feet, "soapstone;" at ninety seven feet, cement rock; at one hundred and seven feet, "soapstone" again; at one hundred and thirty-eight feet, "brownstone and lime rock." The "brownstone and lime rock" was not penetrated to any depth and it is not possible, perhaps, to assert positively what it was; but it is believed to be the same as the Lower Helderberg rock underlying the cement rock on the river.

The material taken from the new intake shaft and tunnel was dumped indiscriminately upon the beach. It has since been spread out, covered with soil, planted with grass and trees and made into a park. It was impossible, for the most part, to sort out the different components of the mass, or to determine except in a general way their original order of superposition. Cement rock and "soapstone" were mingled with each other and are alike disintegrating and turning to clay. The "soapstone" is a lumpy, nodular shale of a greenish-gray color, soft, when wet, hardening into something very like rock when dry, and turning very rapidly to clay under exposure to the rain and air. It strongly resembles some layers of the cement quarry rock, whose lowest and highest layers possess much the same qualities. Portions of the soapstone carry fossils in an excellent state of preservation, of the same species, for the most part, as those found at the quarry on the river. Mixed in with the "soapstone" are very hard layers, from one to four inches in thickness, largely composed of shells of *Chonetes scitulus* Hall, of a gibbous form, associated with *Tentaculites bellulus* Hall. The same form of *Chonetes* is also found amid the softer material in the dump and in the lower division of the quarry. The *Tentaculites* is also found at the cement quarry, but not so abundantly. A distinctly flatter variety of the same species of *Chonetes* is found in other portions of the "soapstone," and in the upper layers of the quarry.

Finely preserved shells of *Spirifer euryteines* Owen, *S. asper* Hall, and *Atrypa reticularis* L., the latter with coarse plications, are found in the "soapstone" and in the upper layers at the quarry. Other portions of the "soapstone" are almost, or wholly, devoid of fossils, and in this they resemble some of the softer layers near the bottom of the quarry.

In the mass dumped on the beach were found some large stones, having the appearance of boulders, composed of hard rock similar in color to the harder cement rock, but traversed by very hard white seams of a siliceous character. These seams are full of fossils, most of which are also found at the quarry. Such are *Chonetes scitulus* Hall, of the gibbous variety, *Spirifer subvaricosus* H. & Wh., *Palaeoneilo fecunda* Hall, and many others. Associated with these, however, are a number of gastropods, which give a distinctive character to the fauna of these seams; gastropods, with the exception of *Platyceras*, being very rare at the quarry. Among the gastropods of the white seams are *Bellerophon* near *pelops* Hall, and species of *Pleurotomaria*, *Cyclonema* and *Loxonema*.

The black shale, mentioned above as the first rock formation penetrated by the intake shaft, is quite distinct from the other materials dumped on the beach. Pieces of it exhibit glacial scratches. Its only fossils are two or three species of *Lingula*. Certain layers are firm and smooth-grained; others are extremely fissile, splitting into thin, rough laminae. There is also a greenish shale, whose exact place in the series is not ascertainable, also carrying species of *Lingula*. These shales are not found anywhere else in place in the state, though small rounded pieces are not uncommon in the drift. They seem to have given way everywhere else under the erosive action of the glaciers.

The rock at the cement quarry on the river comprises two main subdivisions distinguished, to some extent, by differences in their fossils, but still more noticeably by the different states of preservation in which their fossils are found. The lower subdivision is twenty-one feet in thickness. Fossils are abundant in this division, but principally in the form of casts and

impressions. Almost the only ones which are well preserved are specimens of *Lingula*, *Orbiculoidea* and *Conularia*; the plates, scales and teeth of fishes; and some plant remains in carbonized form. At the top of this section is a very hard layer about six feet in thickness, containing cavities lined with crystals of calcite and pyrite. This layer is very rich in fossils, very few forms being absent from it which are found in any part of the quarry; and it is especially distinguished by the multitude of its cephalopod and fish remains. The layers below this one are softer, some of them very soft indeed, and are on the whole less rich in fossils; but the surfaces of some of the lower layers are covered with pyritized shells of brachiopods, mainly *Chonetes scitulus* Hall, of the gibbous form, and *Delthyris consobrina* D'Orb.

The upper subdivision comprises the upper four feet of the quarry. Its surface has been smoothed by glacial action. Most of its fossils are found as casts in the section below, but here the shells are often preserved. Much of the rock of this division is of a lumpy, nodular character, and suffers rapid disintegration under atmospheric influences, the fossils weathering out.

These two sections, at the lake and at the river, are not precisely alike but are easily correlated with each other. The entire series of Milwaukee Devonian rocks may therefore be conveniently subdivided as follows, the section at the water tunnel being designated A, and the section at the cement quarries B.

A 4. The *Lingula*-bearing shales.

A 3. That portion of the "soapstone" carrying shells of *Spirifer euryteines* Owen, *S. asper* Hall, and *Atrypa reticularis* L., and the flat variety of *Chonetes scitulus* Hall; being the upper "soapstone" of the City Engineer's section.

A 2. This includes the thin hard layers so rich in specimens of the gibbous variety of *Chonetes scitulus* Hall, and *Tentaculites bellulus* Hall. It also includes portions of "soapstone," probably the lower "soapstone" of the City Engineer's section, containing the same variety of *C. scitulus* Hall, and *Conularia*. Its relations seem to be with subdivision B 1 of the quarry rock.

A 1. This consists of the thin white seams, whose relations are not definitely known.

B 2. The upper four feet of the quarry rock, corresponding with A 3.

B 1. The lower twenty-one feet of the quarry rock, including the very hard six-foot layer and several softer and less fossiliferous ones. This corresponds with A 2.

Very likely subdivision B 1, at the cement quarry, could be still further subdivided, the exceedingly hard layer at the top being especially worthy of a place by itself. It is sufficient, however, at present to say that this layer probably carries all the fossils of the layers below it except the plants—which come from further down—most of those above, and in addition a large number of fossils peculiar to itself. Among the latter are most of the fishes, most of the cephalopods, a few brachiopods and many pelecypods.

In the following table an attempt has been made to bring together the fossils of the several subdivisions for purposes of comparison. The lists are not exhaustive. Even at the cement quarry, which has been the most thoroughly examined, new species are occasionally found. The faunas of the shale and “soapstone” are less perfectly known, owing to the limited opportunity afforded for their study. Yet the formation has already furnished in the neighborhood of two hundred species, a remarkably rich collection from so limited a territory.

The determinations of species are in some cases provisional. The specimens of *Chonetes* and *Spirifer* have been submitted to Professor R. P. Whitfield and Mr. Charles Schuchert. The fish remains have been identified by Dr. C. R. Eastman and the crinoids by Mr. Stuart Weller. In other instances some of the names may have to be changed. Some of the species are new and have not yet received names.

It will be noticed that some species which are mentioned in the *Geology of Wisconsin* as coming from this formation are not contained in this list. Among them are *Chonetes coronatus* Conrad; *Productella spinulicosta* Hall and *Trematospira hirsuta*

Hall, all of which were probably determined from imperfect casts, or may have been taken from erratic blocks wrongly supposed to have been derived from this formation. Others, like *Spirifer granuliferus* Hall, *S. audaculus* Conrad, *S. angustus* Hall, and *S. euryteines*, var. *forficulus* Hall, were probably mistaken identifications, justified at the time, but based upon casts of *Spirifer euryteines* Owen, which here exhibits great variations of form. Shells of the last named species are rarely found at the quarry, and only in one or two places, not in the rock but in the soil above composed of disintegrated rock. They are quite abundant in the upper "soapstone" from the intake. It is not probable that any had been unearthed at the time of the publication of the *Geology of Wisconsin*. They are distinguished by clearly marked lines of fine striation.

The writers have not attempted the correlation of the Milwaukee fauna with the faunas of other localities, but leave that interesting task to more competent hands. The *Spirifers* of the list, however (*S. iowaensis* Owen = *S. pennatus* Owen; *S. asper* Hall; *S. euryteines* Owen = *S. parryanus* Hall = *S. capax* Hall; and *S. subvaricosus* H. & Wh.) show an obvious relation to certain Devonian faunas of Iowa. It is proper to state that the shell here identified as *S. subvaricosus* H. & Wh. was by Mr. Schuchert considered to be a primitive form of *S. bimesialis* H., another Iowa species. Professor Whitfield, however, considers the identification as *S. subvaricosus* to be correct. Specimens of the shell from B 2, in which the beak has been ground down, seem to show a median septum. So do the casts in B. The latter, however, do not generally show the strong plication of fold and sinus, and such have been identified as *Delthyris consobrina*, D'Orb. (= *S. siczac* Hall.) There is in the list a little *Rhynchonella*, identified as *R. contracta*, var. *saxatilis* Hall, which, if properly named, belongs also to the Rockford and High Point faunas. The Milwaukee specimens of *Schizophoria striatula* Schl. (= *Orthis impressa* Hall) are a form with a wide and not very deep sinus. Occasional forms are found resembling *Schizophoria tulliensis* Vanuxem, and *S. macfarlandi* Meek.

A partial correlation of the fish remains has been furnished us by Professor Eastman. It is as follows :

Dinichthys pustulosus, Eastman—Hamilton Group of Iowa, Illinois and New York ; Upper Devonian of Iowa.

D. tuberculatus, Newberry—Chemung Group of Pennsylvania ; Upper Devonian of Belgium.

Ptyctodus calceolus, N. & W.—Hamilton Group of Iowa, Illinois, Missouri, Manitoba ; Upper Devonian of Iowa.

Heteracanthus uddeni, Lindahl—Hamilton Group, Buffalo, Ia.

Onychodus sigmoides, Newberry—Corniferous Group of Ohio and New York ; Chemung Group, Delaware county, N. Y.

Acantholepis fragilis, Newberry—Corniferous of Ohio & New York.

Sphenophorus, sp.—Chemung Group of Pennsylvania (*S. lilleyi* Newb.)

NOTE.—In the following tables the position of the various species in the different subdivisions is indicated according to their relative abundance by the letter A, abundant ; C, common ; O, occasional ; R, rare.

FAUNA OF THE MILWAUKEE DEVONIAN FORMATION

	A ₄	A ₃	A ₂	A ₁	B ₂	B ₁
PISCES						
<i>Acantholepis fragilis</i> Newb. (= <i>A. pustulosa</i> Newb.)					Occasional small fish remains	R
<i>Cladodus</i> sp.						R
<i>Dinichthys pustulosus</i> Eastman						R
<i>D. tuberculatus</i> Newberry						R
<i>D.</i> sp.						R
<i>Heteracanthus politus</i> Newberry						R
<i>H. uddeni</i> Lindahl						R
<i>Onychodus sigmoides</i> Newberry						R
<i>Palaeomylus greenei</i> Newberry						R
<i>Phlyctaenacanthus telleri</i> Eastman						R
<i>Ptyctodus calceolus</i> N. & W.						R
<i>P. ferox</i> Eastman						R
<i>Rhynchodus excavatus</i> Newberry						R
<i>Sphenophorus</i> sp.						R
<i>Titanichthys</i> sp.						R
Scales of fishes, of undetermined species.						O
CRUSTACEA						
<i>Echinocaris</i> (= <i>Ceraliocaris</i>) sp.						R
<i>Phacops rana</i> Green.					C	O
<i>Proetus</i> sp.					R	R
<i>P.</i> sp.				R		
CEPHALOPODA						
<i>Gomphoceras breviposticum</i> Whitfield						O
<i>G. fusiformae</i> Whitfield						O
<i>G.</i> , at least ten other species, large and small, including so-called "Horses' Hoofs," all from B ₁ .						
<i>Goniatites</i> sp.						R
<i>Gyroceras eryx</i> Hall						C
<i>G.</i> , three or four other species						R
<i>Orthoceras</i> , large, like <i>O. bebryx</i> Hall						R
<i>O.</i> , very slender				R		
<i>O.</i> , one or two other species.					R	R
PTEROPODA						
<i>Conularia</i> sp.		?	R		R	R
<i>Hyolithes</i> sp.				R	R	R
<i>Tentaculites bellulus</i> Hall		A		A		R
GASTROPODA						
<i>Bellerophon</i> , near <i>pelops</i> Hall						
<i>Callonema</i> sp.				R		
<i>Cyclonema</i> sp.					R	
<i>Loxonema</i> sp.				R		
<i>Murchisonia</i> sp., minute, preserved in pyrites.						R
<i>M.</i> sp., large					R	
<i>Platyceras auriculatum</i> Hall					R	
<i>P. carinatum</i> Hall					R	
<i>P. erectum</i> Hall					R	
<i>P.</i> , two other species					R	
<i>Pleurotomaria</i> , two or three species.				R		

	A ₄	A ₃	A ₂	A ₁	B ₂	B ₁
PELECYPODA						
<i>Actinopteria</i> sp.....				R		
<i>A. sp.</i>					R	R
<i>Cimularia elongata</i> Conrad.....						R
<i>Chidophorus oblongus</i> Hall.....						R
<i>Goniophora hamiltonensis</i> Hall.....						R
<i>Grammysia nodocostata</i> Hall.....		R				R
<i>G. subarcuata</i> H.....						R
<i>G. sp.</i>						R
<i>Leda</i> , near <i>rostellata</i> Conrad.....						R
<i>Lyrropecten</i> , near <i>interradiatus</i> Hall.....						R
<i>Modiola precedens</i> Hall.....						R
<i>Modiomorpha affinis</i> Hall.....						R
<i>M. alta</i> Conrad.....						R
<i>M. concentrica</i> Conrad.....					R	O
<i>M. macilenta</i> Hall.....						R
<i>M. mytiloides</i> Hall.....						R
<i>M. ponderosa</i> Hall.....						R
<i>M. quadrula</i> Hall.....						R
<i>M. subulata</i> Hall.....						R
<i>M. subulata</i> var. <i>chemungensis</i> Hall.....						R
<i>Mytilarca umbonata</i> Hall.....						R
<i>M. (Plethomytilus) oviformis</i> Conrad.....						R
<i>Nucula corbuliformis</i> Hall.....						O
<i>N. randalli</i> Hall.....						O
<i>Nuculites oblongatus</i> Conrad.....				R		
<i>Palaeoneilo brevis</i> Hall.....		R				
<i>P. constricta</i> Conrad.....				O	O	C
<i>P. elongata</i> Hall.....						R
<i>P. emarginata</i> Hall.....				R		R
<i>P. fecunda</i> Hall.....		O		R	O	R
<i>P. plana?</i> Hall.....				R		
<i>P. sp.</i>		R				
<i>Paracyclas elliptica</i> Hall.....				R		
<i>P. tenuis</i> Hall.....						R
<i>Pterinopecten</i> , near <i>intermedius</i> Hall.....		R				
<i>Sphenotus</i> , near <i>cuneatus</i> Conrad.....						R
<i>S.</i> , near <i>clavulus</i> Hall.....						R
Many other species of Pelecypoda, imperfectly preserved in B ₁						
BRACHIOPODA						
<i>Athyris fulltonensis</i> Swallow.....		R			A	R
<i>A. sp.</i>					R	
<i>Atrypa hystrix</i> , var. <i>occidentalis</i> Hall.....						O
<i>A. reticularis</i> L.....		A	O	O	A	A
<i>A. spinosa</i> Hall.....						R
<i>Camarotoechia</i> near <i>sappho</i> Hall.....						R
<i>C. contracta</i> , var. <i>saxatilis</i> Hall.....		R		R	R	R
<i>Chonetes scitulus</i> Hall—flat variety.....		O			A	
<i>C. scitulus</i> Hall—gibbous variety.....			A			
<i>C. vicinus</i> Castelnau (= <i>C. deflectus</i> Hall).....						C
<i>Craniella hamiltoniae</i> Hall.....						R

	A ₄	A ₂	A ₂	A ₁	B ₂	B ₁
ANNELIDA						
<i>Cornulites</i> sp.					R	
<i>Spirorbis</i> , one or two species, on Brachipods					R	R
ECHINODERMATA						
<i>Melocrinus milwaukensis</i> , Weller					R	
<i>M. milwaukensis</i> var. <i>rotundatus</i> Weller					R	
<i>M. nodosus</i> Hall.					R	
<i>M. nodosus</i> var. <i>spinosus</i> Weller		R			R	
<i>M. subglobosus</i> Weller.					R	
<i>M.</i> sp.					R	
<i>Pentremitidea filosa</i> Whiteaves					R	
<i>P. milwaukensis</i> Weller					R	
<i>Taxocrinus</i> sp.					R	
Crinoid stems of several sorts.					C	
COELENTERATA						
<i>Favosites</i> sp.						R
<i>Heliophyllum halli</i> Ed. & H.						R
<i>Zaphrentis</i> , one or two species.						R
SPONGIDA						
Sp. ?						R
PLANTAE						
About a dozen carbonized forms of land plants of several genera; some threadlike, or with threadlike branches; the largest over four feet long and as much as five inches wide; all somewhat flattened; mainly in the softer layers of B ₁ . Also several species of fucoids, in all layers of both sections.						

As we go to press, Dr. C. R. Eastman, furnishes the following note on the fossil fishes mentioned in the foregoing article :

ELASMOBRANCHS

- Ptyctodus calceolus* N. & W. (Tritons only).
P. ferox East. (Complete dental plates, upper and lower jaws).
Rhynchodus excavatus Newb. (Complete dental plates, upper and lower jaws).
Palaeomylus greenei (Newb.). (Complete dental plates, upper and lower jaws).
Cladodus sp. nov. (Detached teeth).
Heteracanthus politus Newb. (Spines).
H. uddeni Lindahl. (Spines).

“PLACODERMS” (including *Arthrodira*)

Acantholepis fragilis Newb. (= *A. pustulosa* Newb.). Fragmentary spines).

Phlyctaenacanthus telleri Eastm. (Fragmentary spines).

Dinichthys tuberculatus Newb. (Fragments of dermal armor).

D. pustulosus Eastm. (Crania, dorsal and ventral plates; also portions of the dentition).

Large, thin plates belonging to two as yet unknown Dinichthyids, probably *Dinichthys* or possibly akin to *Titanichthys*.

Sphenophorus sp. nov. (Fragments of dermal plates).

CROSSOPTERYGIANS

Onychodus sp. (Clavicle and other plates very suggestive of *O. sigmoides* Newb., but as yet no teeth nor scales, sufficient to prove specific identity).

Several varieties of scales and other fragments.

CHARLES E. MONROE.

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MILWAUKEE, WIS.

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